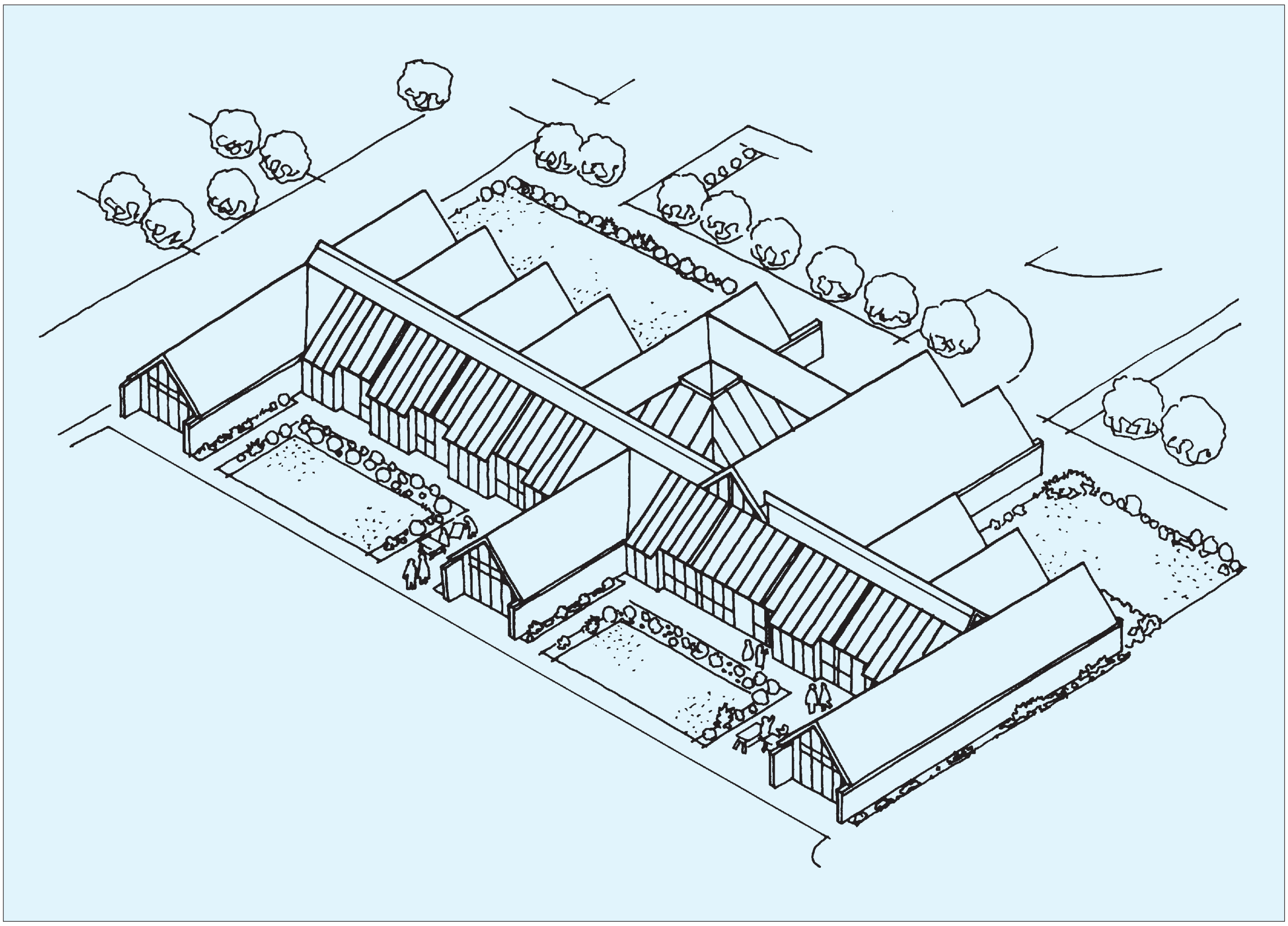
Leaflet 32

Passive solar design
Netley Abbey Infant School

- Very low primary energy consumption – 142 kWh/m^2
- Energy savings of 25%
- Lower capital cost than average for schools



The main passive solar feature is a conservatory running the length of the south-east elevation

ENERGY EFFICIENCY

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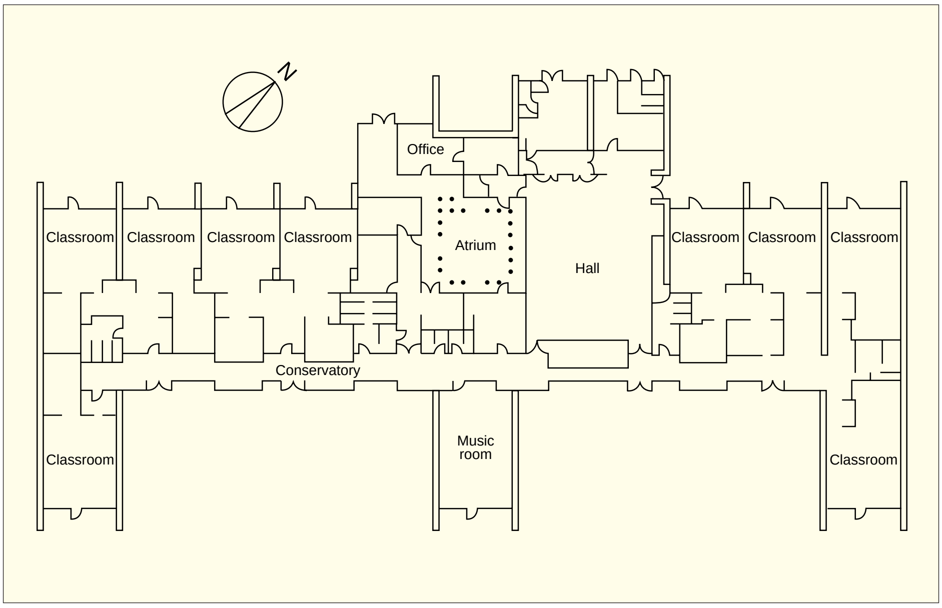
Background

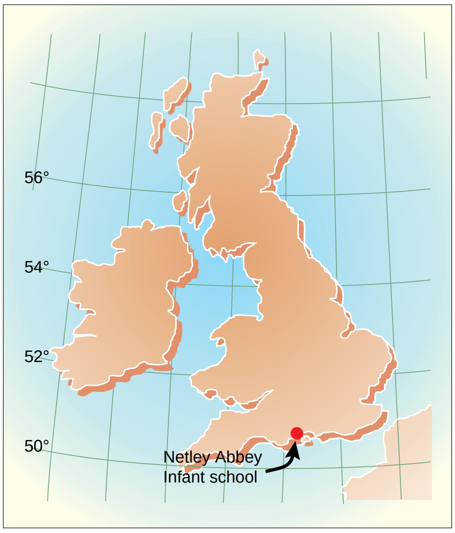
Netley Abbey Infant School was designed to accommodate 220 pupils between the ages of four and eleven. It has seven classrooms, shared spaces, ancillary areas and catering facilities, and has been occupied since September 1984.

The new school, designed to replace two Victorian buildings, was considered by the client, Hampshire County Council, as a test bed where passive solar design could be investigated as a complementary strategy to conventional energy saving measures. The scheme originated from studies at the Martin Centre, Cambridge, into solar preheated ventilation of schools.

Situated on the south-eastern boundary of the existing junior school, the site is exposed to open fields to the north and low density, two-storey housing to the south. Solar access is good. Apart from coastal breezes which augment prevailing south-westerly winds, there are no unusual climatic conditions around the site.



Plan of the school



The school is near Southampton

Design and solar strategy

The design strategy was to build a highly insulated envelope and, instead of using solar direct gain and thermal mass, to use solar gain in a conservatory to preheat ventilation air.

Ventilation requirements within schools are considerable and with increasing levels of thermal insulation, ventilation heat losses are relatively larger. Therefore the designers used the air temperature increase (above that of outside air) which resulted from solar radiation in the conservatory, to reduce the amount of heat required to warm incoming ventilation air.

A direct gain strategy reliant on thermal mass and large areas of glazing might have resulted in problems when trying to avoid overheating and glare within the teaching areas.

A conservatory runs along the length of the south-east facade of the school acting as the main circulation route and linking teaching, music and resource areas. The conservatory contributes to both the heating and ventilation requirements of the school by acting as a thermal buffer and preheating ventilation air.

An atrium adjacent to the main entrance links the administration areas within the school and provides daylight to the hall, but serves no overt passive solar heating role.

The high pitched roofs contribute to stack effect and house service equipment, but have low eaves providing an appropriate scale for the children in their classrooms.

Computer thermal simulation showed that a slight advantage both in terms of energy and comfort could be gained by a south-easterly orientation.

Winter solar preheating

A combination of 70% recirculated air and 30% make-up preheated air from the conservatory is supplied to teaching areas during the heating season. The 30% make-up proportion can be increased to 100% by pushing a special 'green button' in the classrooms, which shuts off the recirculated air for 30 minutes. This button controls an electrically operated damper in the air handling equipment. If the make-up air is too cold, it is heated to an appropriate comfort level.

A thermostat, installed in each teaching space and set to 19°C, switches off the air handling fan. If the 'green button' is pushed when the temperature is already satisfied, the fan circulates make-up air from the conservatory at whatever temperature it has reached.

North elevation showing air inlet louvres above the fire doors which are opened to provide extra ventilation

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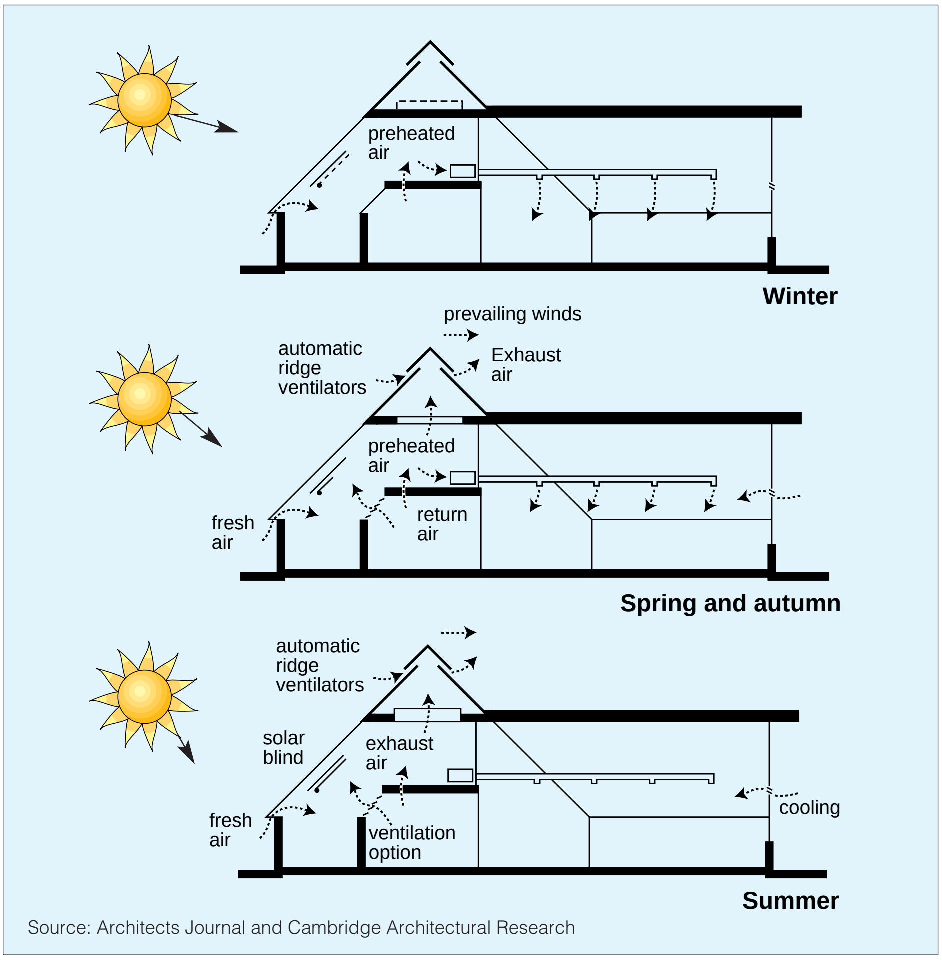

Diagramatic section showing design for seasonal operation

Louvre windows to control air movement between conservatory and classroom

South-east facade: showing conservatory

Summer ventilation
The solar strategy relies on a combination of stack effect generated within the conservatory and wind effect caused by the form of the roof. Air is drawn, via grilles in the north gable walls, through the teaching areas and into the conservatory by stack effect or wind-induced suction at the ridge of the roof, but the effect is reduced if the conservatory doors are opened.

The air handling equipment is not isolated from the boilers. For this reason it cannot be used to distribute fresh air in the summer months. The toilets are mechanically ventilated.

Control strategy
Compatibility between the solar strategy and orthodox services was an important design consideration.

Both manual and automatic controls are necessary to integrate the passive and mechanical heating and ventilation modes of the design.

Manual control of adjustable louvres, in the quiet areas at the conservatory end of each classroom, is designed to allow movement of air from teaching areas to the conservatory.

Automatic 'greenhouse' vents, connecting the conservatory to a continuous ridge vent on the roof, open to dissipate stale and solar heated air from the conservatory.

To enable occupants to both reduce solar gain and dissipate its effect, there are roller blinds fitted to the sloping glazing and adjustable louvres in the external wall of the conservatory.

Daylighting
All the classrooms, except one, rely on north lighting from the end gable of the room for a large proportion of their natural light. Additional daylight is also obtained from high level glazing separating the conservatory from the rear of the classrooms.

Electric lighting
The teaching areas have low energy fluorescent lighting to supplement daylight from the windows and conservatory.

Heating and hot water
Two 50 kW boilers supply the warm air heating system which is augmented with solar pre-heated air from the conservatory.

Each teaching area has an air heater battery located at high level at the rear of the conservatory. Warm air is delivered to each classroom via a coaxial duct suspended below ceiling level. Stale air is drawn from classrooms through extract slots on top of the duct to be partly recirculated via the heater battery.

Domestic hot water is supplied by both an Andrews water heater and localised water heaters.

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Construction

External walls

The external walls comprise two-thirds window walling and one-third cavity wall. The window wall is constructed using timber framing supported by a steel beam and clad with toughened glass and insulated infill panels. The wide cavity wall, 450 mm wide, is constructed using two silicate half-brick skins. Both constructions have 75 mm of polystyrene insulation.

Internal walls

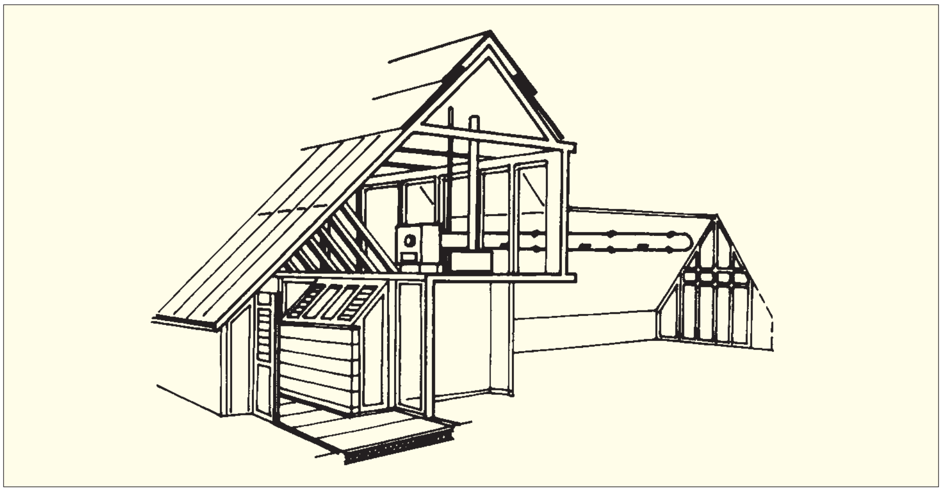
Diaphragm walls are constructed using calcium silicate bricks. Other internal walls are constructed using half and single brick walls. Softwood screens are constructed using ply-stained plasterboard/fibreboard with laminated glass.

Floor

The ground floor comprises carpet on tongue and groove chipboard on battens on a 125 mm concrete slab. Placed around the base of the slab to a depth of 1800 mm is 40 mm of polystyrene insulation. The conservatory has paving slabs on polyethylene slab supports. The mezzanine floor is tongue and groove chipboard on timber joists with a glass fibre quilt on a vapour barrier.

Roof

This is constructed from timber with artificial cement slates and is insulated using 150 mm of glass fibre quilt. The roof space is ventilated via permanent ridge ventilation. The conservatory roof is twin wall polycarbonate at 45° pitch.



Classroom with coaxial duct work above teaching area and high level glazing to the conservatory

Classroom showing duct at high level and north fire exit doors

Performance

Thermal comfort

Monitoring showed that the thermal buffering and preheating provided by the conservatory was effective in reducing energy consumption. However, using preheated air from the conservatory as fresh air, during the winter, was not entirely successful. Stale air from the classrooms leaked back into the conservatory through insufficiently sealed junctions between ducts, glass louvres and doors, and was then recirculated as 'fresh' air in addition to the air that was already being recirculated by design. Another problem was that the fresh air was not perceived as 'fresh' since it came into the classrooms as warm air.

Summer overheating was largely avoided. The recommended upper limit of 27°C in classrooms was only exceeded on a few days and was well within the 10 days a year specified by the Department for Education and Employment (D*f*EE) Design Note 17. However, the conservatory is also the main circulation route. Staff and pupils use this unheated area throughout the year and in winter are reluctant to accept the designer's intention that it is unheated and solely dependent on solar and internal gains.

Noise or condensation had not been a problem but a majority of the staff complain of draughts, mostly coming from the conservatory. The opening and closing of doors between the conservatory and classrooms resulted in air entering the classrooms which was too cold in winter and too hot in summer.

U-values	W/m²°C
Roof	0.3
Floor	0.4
Walls	0.4
Single glazing	5.6
Polycarbonate	2.8

Ventilation

Under intended design conditions, the ventilation rates were only one-quarter of those required by the D*f*EE Design Note 17 (30 m³/person/hour). The ventilation design did not work well, as insufficient air was drawn through the classrooms for the following reasons.

- Lack of openable windows to the exterior.
- Limited height in the conservatory produced a weak stack effect and consequently ventilation to the classrooms tended to be wind dominated.
- The small ventilation inlet area available in the north gable of each classroom. The sliding shutters halved the available area.
- Some classrooms lacked either rooflights or louvres into the conservatory.

Staff responded to inadequate ventilation rates in the teaching areas by opening the doors between classrooms and conservatory. Ventilation was further increased by opening the emergency exit door in the north gable of each classroom. This helped to keep temperatures close to the external.

Ventilation could be improved by providing opening windows and larger openings for incoming and outgoing air.

Air handling unit at high level supplying preheated conservatory air to classroom

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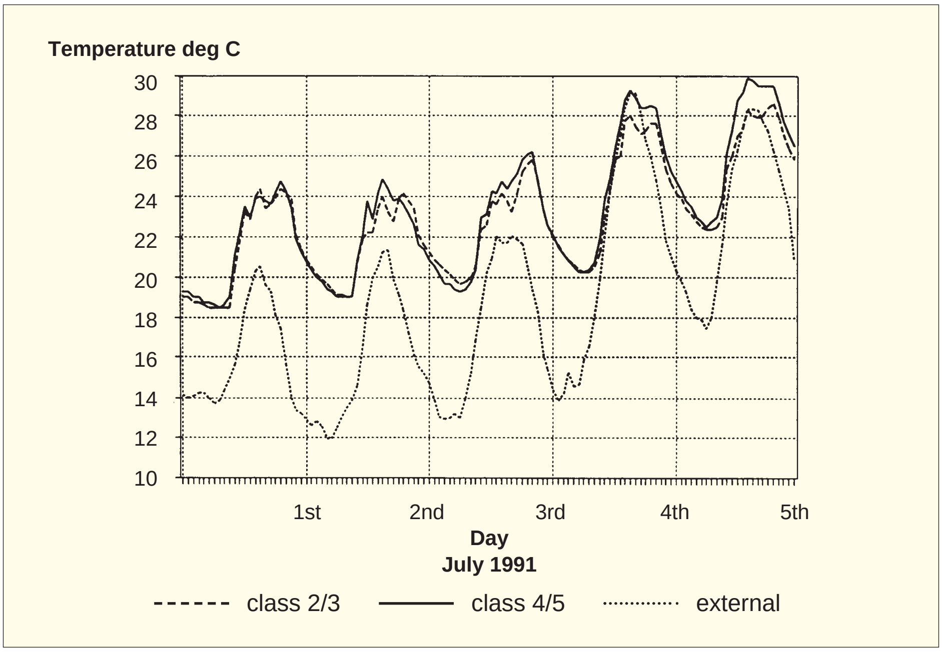
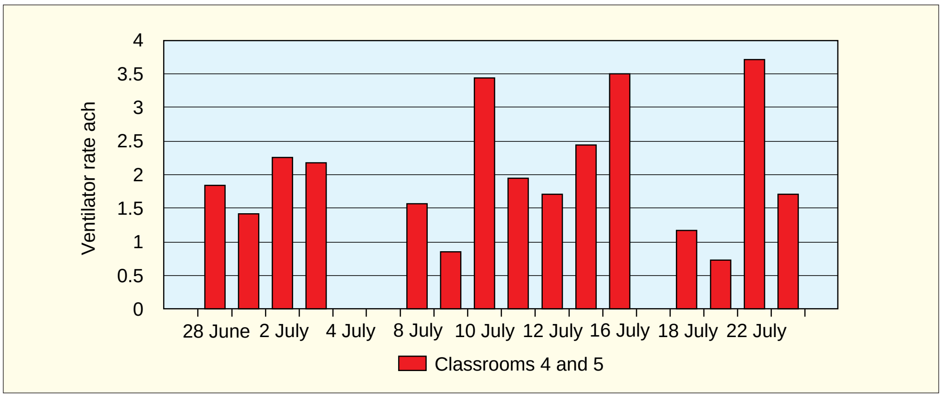
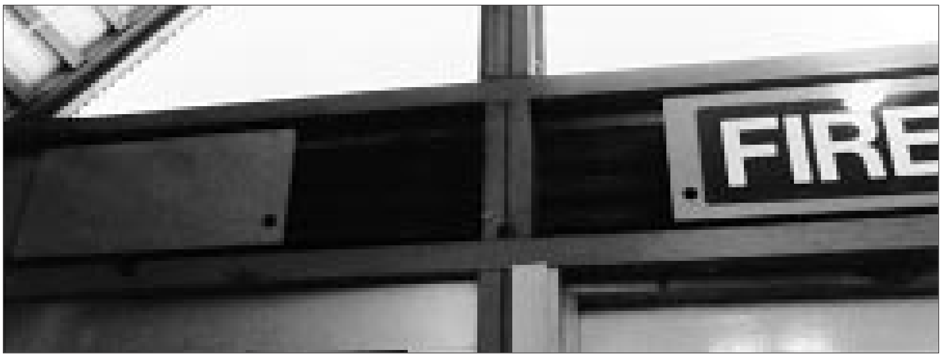


Classroom temperatures only rose above design limits on two exceptionally warm days

Conservatory showing blinds and thermal mass of floor



Typical summer ventilation rate for classroom was lower than anticipated



Air inlets at north end of classroom were not large and were obstructed

Controls

Manual control of Netley school was a specific design intention. Both the preheating and ventilation strategies are dependent on the occupants' understanding of how to control the system. The staff had only a partial understanding of the controls and most wanted greater control over their environment than either they or the systems could achieve.

Designers of innovative buildings such as Netley should not only supply the intended users with sufficient information to operate heating and ventilation strategies satisfactorily, but should not expect too much from users. The simpler the better.

Daylighting

In the classrooms the daylighting strategy has resulted in problems with glare from the windows, causing contrast to the whiteboard on the window wall.

However, levels of illumination in the conservatory are perceived to be neither too bright nor too dim and the blinds provide adequate control of glare.

Analysis of energy use

Netley School was monitored over three heating seasons starting in 1985/86.

Over a year of detailed monitoring (1986/87) annual fuel use was as follows:

	Delivered		Primary	
	kWh/m^2	%	kWh/m^2	%
Space heating	60	69	65	46
Water heating	9	10	9	6
Lighting and power	18	21	68	48
Total	87		142	

The results of the analysis of separate areas of the building indicate good solar preheat performance and in the year 1987/88 the conservatory made a 25% contribution to the school's energy balance.

Savings due to the conservatory in the spring and autumn were from 40 to 80% of the predicted energy consumption of the school if it had been built without the conservatory.

Improved energy performance in the latter part of the monitored period suggests that the occupants may have acquired a greater understanding of how to use the building.

Construction costs

The capital construction costs of building Netley School, normalised to the fourth quarter of 1990, totalled £417/m^2 gross floor area (GFA). This is less than the average building price for primary/junior schools of £476/m^2 and compares closely with the BCIS mean for middle schools at £393/m^2. It is considerably less than nursery schools at £612/m^2.

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The roof was the largest single element of cost at 30% of the total capital cost of the school. This was due to the wide roof span, large polycarbonate glazed area, rooflights and timber finishes to the sloping roof ceiling.

Lessons from this study

Staff were reluctant to accept the unheated conservatory as an area which was not always habitable. They were also confused about how the controls combined solar elements of the design with the heating system. Occupants need to be party to the designers' intentions; controls should be easy to understand and operate.

Although the preheating of air via the conservatory produced large energy savings, the summer ventilation was not as successful. The roof and conservatory were designed to induce ventilation in the classrooms, but the stack effect strategy was less successful than intended in providing satisfactory levels of air quality. Larger and more convenient openings needed to be provided for incoming and outgoing air – the teachers would have liked openable windows to the outside. Opening rooflights at the south end of the classrooms and larger openings at the north end would have allowed more cross ventilation.

The mechanical ventilation system could also have been modified to provide fresh air from outside and to be used for summer ventilation.

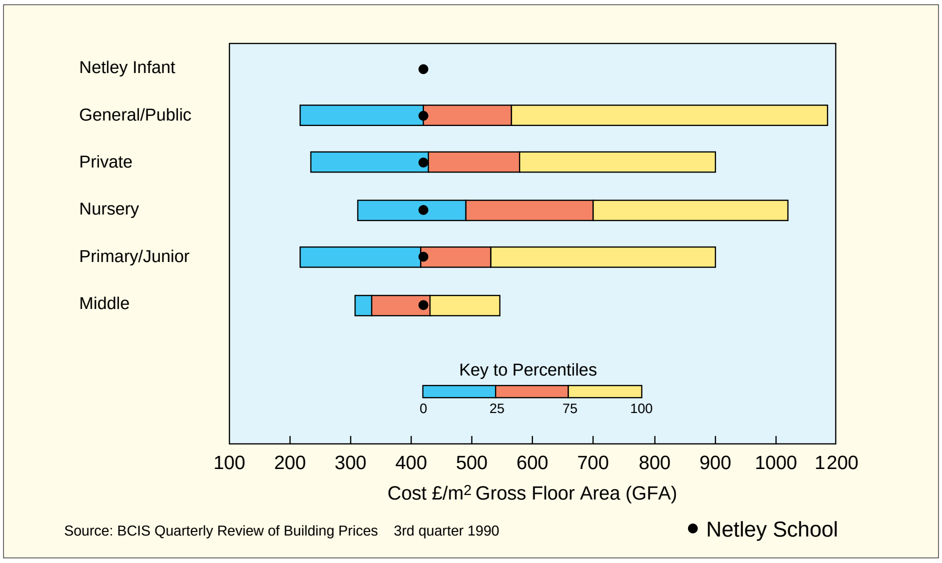
The high insulation level makes a significant contribution to energy saving. However, a more compact plan and a reduction of the area of north-facing glazing and the use of south-facing rooflights instead to bring light into the centre of the plan, would have reduced heat losses further.

Conclusion

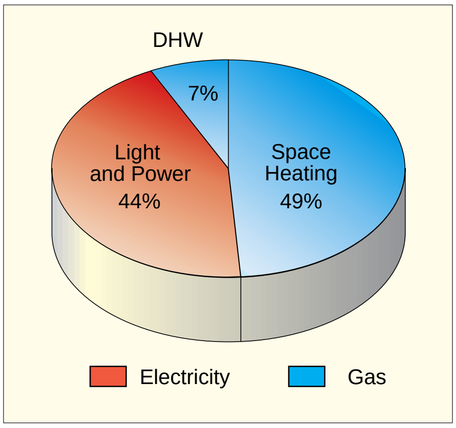
The main passive solar feature of the school is the unheated conservatory which runs the length of the south-east facade. This contributes to both the heating and ventilation requirements of the teaching areas. By combining high levels of insulation and an effective solar preheating strategy, the school has low delivered energy usage – 87 kWh/m^2 – and it was constructed for less than the average building price for primary/junior schools. Thus the passive solar features in this innovative building have been incorporated at no extra cost.

Computer-aided thermal simulation enabled the concept of solar preheating to be developed and then incorporated into the building at an early stage by the designers.

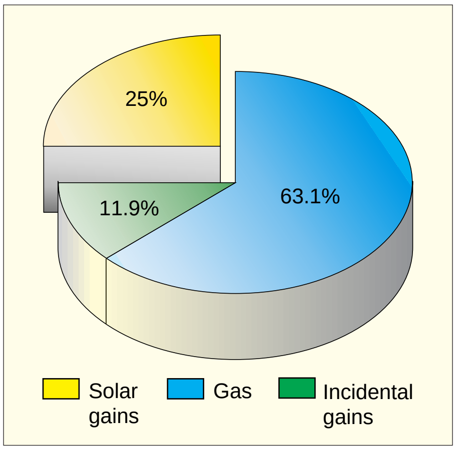
Although the design achieved a solar contribution of 40% to the space heating energy, it was less successful in ventilating the building. Staff responses seem equally divided into positive and negative comments when considering whether the school was a comfortable place to work in.



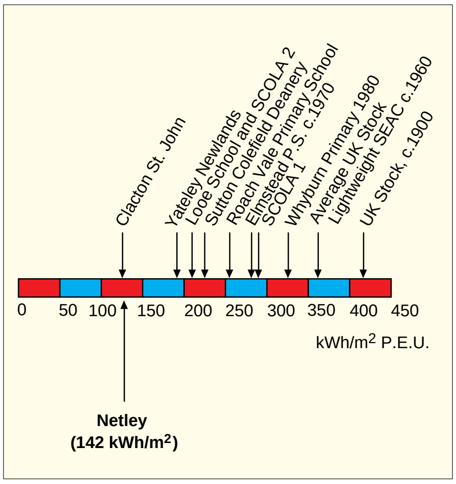
Ranges of building prices for schools, excluding external works and contingencies



Breakdown of primary energy use (total 128 000 kWh)



Solar contribution to space heating



Annual primary energy targets and comparisons

Further reading

Further General Information Leaflets in this series are being developed.

Project data

Project team

Client		Hampshire County Council
Architect		Hampshire County Council
M & E Consultant		Fuller and Partners
Energy Consultant		N Baker
Design criteria		
Occupancy		220 pupils
Ventilation rate		2 ach
		10 - 30 m^3/hr/p
Lighting		200 lux
Internal temp		14 - 24°C
Building information		
Volume -	gross	3092 m^3
	heated	2256 m^3
	conservatory	586 m^3
Ground floor area (excl. conservatories and atrium)		835 m^2
	conservatory	105 m^2
	atrium	95 m^2
Roof area		1180 m^2
Wall areas -	single glazing	184 m^2
	brickwork	90 m^2
	stud framing	83 m^2

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